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U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR

10/030952

INTERNATIONAL APPLICATION NO.  
PCT/AU00/00830 ✓INTERNATIONAL FILING DATE  
10 July 2000 ✓PRIORITY DATE CLAIMED  
09 July 1999 ✓

TITLE OF INVENTION

IMAGE DATA ANALYSIS OF OBJECTS

APPLICANT(S) FOR DO/EO/US

RMS RESEARCH MANAGEMENT SYSTEMS INC.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
  - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☒ has been transmitted by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ A copy of the International Search Report (PCT/ISA/210).
8. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
  - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ have been transmitted by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☐ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

## Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☒ Certificate of Mailing by Express Mail
20. ☐ Other items or information:

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Kurt Malmstrom

Serial No:

Filed:

Title: IMAGE DATA ANALYSIS OF  
OBJECTS

Examiner:

Art Unit:

Date: January 8, 2002

**PRELIMINARY AMENDMENT**

Hon. Commissioner of Patents  
and Trademarks  
Washington, D.C. 20231

Sir:

Please amend the claims of the above-identified application in accordance with the  
Clean Version and Version With Markings attached herewith.

REMARKS

The above-identified application is a National Stage application derived from  
International Application Serial No. PCT/AU00/00830 filed on July 10, 2000, now published  
on January 18, 2001, International Publication No. WO 01/04607, which derives from  
Australian Patent Applications Serial Nos. PQ2828 filed on September 14, 1999 and PQ1544  
filed on July 9, 1999. A chain of codependency exists such that the effective filing date of the

instant application is July 9, 1999, the filing date of the first of these applications.

Claims 1 - 12 are pending in the instant application. Entry of the amendments is respectfully requested. No new matter is added. The amendments are made merely to better comply with U.S. Patent Office requirements.

The Examiner's attention to the present application is greatly appreciated. It is believed that the claims in this case are in condition for allowance and notice thereof is respectfully solicited. If there are any remaining issues that need to be resolved, it is respectfully requested that a telephone call be placed to the undersigned.

Respectfully submitted,

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## VERSION WITH MARKINGS TO SHOW CHANGES MADE

### AMENDMENT OF THE CLAIMS

Please amend the claims as follows:

1. A method of analysing colour image data relating to a target object to derive or predict a property of the object of which colour is an indicator, the method including the step of processing the colour data to derive light intensity independent measures of colour values, followed by the step of calculating the property of the object utilising the light intensity independent colour measures in a predictive equation in which the light intensity independent colour measures are variables and the property of the object is calculated from solving the predictive equation.
2. (Once Amended) A method of analysing colour image data relating to a target object as claimed in claim 1 wherein the colour image data comprising RGB colour values are obtained by digitising measured RGB values from a colour data capture system using a digitiser, the digitiser having a predetermined intensity normalised offset "k", and wherein the light intensity independent measures of colour values are determined from the equations:  
  
where  $R_i$  is the intensity normalised red value,  $G_i$  is the intensity normalised green value, and  $I$  is the intensity, the intensity variable  $I$  being only used for reconstruction of the RGB colour values.
3. (Once Amended) A method of analysing colour image data as claimed in claim 1 [or 2] wherein the predictive equation is developed from data gathered during a data gathering

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experiment using images captured for real target objects, the method comprising correlating the light intensity independent colour measures obtained from these data with the actual measured property of each of the real target objects to derive the predictive equation by statistical analysis techniques to best fit the data and optimise the prediction of the actual measured property from the light intensity independent colour measures.

4. A method of analysing colour image data as claimed in claim 3 wherein the predictive equation takes the form:

$$\text{Property} = x + y.R_i + z.B_i$$

where x, y, and z are constants of positive or negative value derived by the statistical analysis techniques to best fit the data, and  $R_i$  is the intensity normalised red or blue value,  $G_i$  is the intensity normalised green or blue value.

5. A method of analysing colour image data as claimed in claim 3 wherein the predictive equation takes the form:

$$\text{Property} = a + b.D + c.R_i$$

where a, b, and c are constants of positive or negative value derived by the statistical analysis techniques to best fit the data, D is a dimensional parameter relating to the target object, and  $R_i$  is the intensity normalised red or green or blue value, the predictive equation optionally having further terms relating one or more further dimensional parameters relating to the target object and further intensity normalised red or green or blue value for the same or different sections of the area of the target object.

6. (Once Amended) A method of analysing colour image data as claimed in [any one of

## **VERSION WITH MARKINGS TO SHOW CHANGES MADE**

the preceding claims] Claim 1 wherein the object is a meat object, the property of the meat object being a quantative meat or carcass quality measure, the method including the steps of capturing and processing colour data for the meat object to derive light intensity independent measures of colour values, followed by the step of calculating the quantative meat or carcass quality measure for the meat object utilising the light intensity independent colour measures in a predictive equation in which the light intensity independent colour measures are variables and the quantative meat or carcass quality measure of the meat object is calculated from solving the predictive equation.

7. A method of analysing colour image data as claimed in claim 6 wherein the quantative meat or carcass quality measure is a measure selected from the set consisting of:

the "yield" of a carcass in a standard carcass grading system,

the "conformation" of a carcass in a standard carcass grading system,

the "fat score" of a carcass in a standard carcass grading system,

the "yield grade" of meat from a carcass in a standard meat grading system, and

the "quality grade" of meat from a carcass in a standard meat grading system.

8. A method of analysing colour image data as claimed in claim 7 wherein the quantative meat or carcass quality measure comprises the "yield" of a carcass as defined in the standard Australian carcass grading system.

9. A method of analysing colour image data as claimed in claim 7 wherein the quantative meat or carcass quality measure comprises the "conformation" of a carcass in the EUROP standard carcass grading system.

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10. A method of analysing colour image data as claimed in claim 7 wherein the quantitative meat or carcass quality measure comprises the "fat score" of a carcass in the EUROP standard carcass grading system.

11. A method of analysing colour image data as claimed in claim 7 wherein the quantitative meat or carcass quality measure comprises the "yield grade" of a meat object in the USDA standard meat grading system.

12. A method of analysing colour image data as claimed in claim 7 wherein the quantitative meat or carcass quality measure comprises the "quality grade" of a meat object in the USDA standard meat grading system.



CLEAN VERSIONCLAIMS

1. A method of analysing colour image data relating to a target object to derive or predict a property of the object of which colour is an indicator, the method including the step of processing the colour data to derive light intensity independent measures of colour values, followed by the step of calculating the property of the object utilising the light intensity independent colour measures in a predictive equation in which the light intensity independent colour measures are variables and the property of the object is calculated from solving the predictive equation.
2. A method of analysing colour image data relating to a target object as claimed in claim 1 wherein the colour image data comprising RGB colour values are obtained by digitising measured RGB values from a colour data capture system using a digitiser, the digitiser having a predetermined intensity normalised offset "k", and wherein the light intensity independent measures of colour values are determined from the equations:  
  
where  $R_i$  is the intensity normalised red value,  $G_i$  is the intensity normalised green value, and  $I$  is the intensity, the intensity variable  $I$  being only used for reconstruction of the RGB colour values.
3. A method of analysing colour image data as claimed in claim 1 wherein the predictive equation is developed from data gathered during a data gathering experiment using images independent colour measures obtained from these data with the actual measured property of

## CLEAN VERSION

each of the real target objects to derive the predictive equation by statistical analysis techniques to best fit the data and optimise the prediction of the actual measured property from the light intensity independent colour measures.

4. A method of analysing colour image data as claimed in claim 3 wherein the predictive equation takes the form:

$$\text{Property} = x + y.R_i + z.B_i$$

where x, y, and z are constants of positive or negative value derived by the statistical analysis techniques to best fit the data, and  $R_i$  is the intensity normalised red or blue value,  $G_i$  is the intensity normalised green or blue value.

5. A method of analysing colour image data as claimed in claim 3 wherein the predictive equation takes the form:

$$\text{Property} = a + b.D + c.R_i$$

where a, b, and c are constants of positive or negative value derived by the statistical analysis techniques to best fit the data, D is a dimensional parameter relating to the target object, and  $R_i$  is the intensity normalised red or green or blue value, the predictive equation optionally having further terms relating one or more further dimensional parameters relating to the target object and further intensity normalised red or green or blue value for the same or different sections of the area of the target object.

6. A method of analysing colour image data as claimed in Claim 1 wherein the object is a meat object, the property of the meat object being a quantitative meat or carcase quality measure, the method including the steps of capturing and processing colour data for the meat

## CLEAN VERSION

object to derive light intensity independent measures of colour values, followed by the step of calculating the quantitative meat or carcass quality measure for the meat object utilising the light intensity independent colour measures in a predictive equation in which the light intensity independent colour measures are variables and the quantitative meat or carcass quality measure of the meat object is calculated from solving the predictive equation.

7. A method of analysing colour image data as claimed in claim 6 wherein the quantitative meat or carcass quality measure is a measure selected from the set consisting of:

the "yield" of a carcass in a standard carcass grading system,  
the "conformation" of a carcass in a standard carcass grading system,  
the "fat score" of a carcass in a standard carcass grading system,  
the "yield grade" of meat from a carcass in a standard meat grading system, and  
the "quality grade" of meat from a carcass in a standard meat grading system.

8. A method of analysing colour image data as claimed in claim 7 wherein the quantitative meat or carcass quality measure comprises the "yield" of a carcass as defined in the standard Australian carcass grading system.

9. A method of analysing colour image data as claimed in claim 7 wherein the quantitative meat or carcass quality measure comprises the "conformation" of a carcass in the EUROP standard carcass grading system.

10. A method of analysing colour image data as claimed in claim 7 wherein the quantitative meat or carcass quality measure comprises the "fat score" of a carcass in the EUROP standard carcass grading system.

**CLEAN VERSION**

11. A method of analysing colour image data as claimed in claim 7 wherein the quantitative meat or carcase quality measure comprises the "yield grade" of a meat object in the USDA standard meat grading system.

12. A method of analysing colour image data as claimed in claim 7 wherein the quantitative meat or carcase quality measure comprises the "quality grade" of a meat object in the USDA standard meat grading system.

11. A method of analysing colour image data as claimed in claim 7 wherein the quantitative meat or carcase quality measure comprises the "yield grade" of a meat object in the USDA standard meat grading system.

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IMAGE DATA ANALYSIS OF OBJECTSField of the Invention

This invention relates to image data analysis for objects such as meat carcasses and meat cuts although the invention may also be applicable to other agricultural, mineral or  
5 manufactured objects.

Background of the Invention

In the meat industry, specialist trained and skilled operators are employed, in abattoirs for example, in order to inspect each animal carcass and to provide estimates or gradings of various parameters, such as the predicted saleable meat yield of each carcass. Such  
10 predictions of meat yield and gradings are very important for fixing a fair value for the carcass and for determining uses to which the carcass and meat cuts will be destined. Obviously it is very important for the meat industry generally including producers, processors and consumers that such operators are consistent both within a particular abattoir or processing facility and between different facilities at different place and different times.

15 There have been proposed and developed automated systems for carcass image capture and colour analysis for automating yield predictions or gradings, or at least for providing some objective replacement or supplement to human operators. For predicting the meat yield of a carcass, yield equations have been developed by statistical methodologies such as multiple regression analysis, such yield equations using the colour data to provide  
20 estimates of meat yield. However, the results of such automated analysis and yield predictions have not been of acceptable reliability or at least have been capable of significant improvement.

In the past, in order to predict the yield of meat carcass, i.e. the amount of saleable meat in the carcass, colour data captured by a colour video camera has been utilised in the

form of R, G, and B values (red, green and blue values) in yield equations derived from multiple field runs as described above. Particular care ought to be taken to ensure as far as possible that the R, G and B colour values are reliably and consistently measured both between different sites with different ambient conditions and using different cameras, and 5 also throughout different periods of use, e.g. throughout a day, when lighting conditions can change. Our earlier patent application No. PCT/AU98/00135 (publication No. WO98/39627) provides considerable detail concerning calibration procedures and systems for achieving the reliable and consistent colour measurements.

However we have found that even accurate and repeatable measurements in the form 10 of R, G and B values when utilised in the relevant yield equations can provide predicted yields which are still susceptible of significantly improved accuracy or consistency.

#### Object of the Invention

It is an object of the present invention to provide a method of analysing colour image data relating to a target object to derive or predict more accurately and consistently a property 15 of the object of which the colour is an indicator.

#### Summary of the Invention

According to the present invention there is provided a method of analysing colour image data relating to a target object to derive or predict a property of the object of which colour is an indicator, the method including the step of processing the colour data to derive 20 light intensity independent measures of colour values, followed by the step of calculating the property of the object utilising the light intensity independent colour measures in a predictive equation in which the light intensity independent colour measures are variables and the property of the object is calculated from solving the predictive equation.

Generally, in the field of meat quality grading, the light intensity independent measures of colour values are used in equations developed to predict a quantitative meat or carcass quality measure, e.g. "yield" in Australia, "conformation" or "fat score" in the EUROP grading system, or "yield grade" or "quality grade" in the USDA grading system.

5 For example, in the particular field of meat carcass yield prediction, the method includes the step of processing the colour data for a carcass to derive light intensity independent measures of colour values for the carcass, followed by the step of calculating the meat yield of the carcass utilising the light intensity independent colour measures in a yield predictive equation.

#### 10 Description of the preferred embodiments

It will be convenient to further describe the invention in relation to the particular field for which the invention has been developed, namely beef carcass yield prediction and grading, however it is to be understood that the principles, methods and systems can be adapted to other field of use.

#### 15 Intensity Normalised Colour Space

Considerable development of our beef carcass system ("BCS") for colour data capture and analysis has been towards achieving acceptable site-to-site consistency. It has been eventually established that the existing methods of lighting distribution compensation on a plane (particularly by calibration processes to minimise effects of lighting changes) did not  
20 adequately remove lighting variations in RGB space. To minimise effects of these variations, the present invention was developed involving use of an intensity normalised colour space. That is, the intensity component was removed from the measurements leaving only colour.

#### Intensity Normalised Components

The intensity normalised class CRiGiI has been adapted from the prior CRGB class consisting of Red, Green and Blue values. The class consists of the member variables Ri; Gi; and I; where Ri is the intensity normalised red value, Gi is the intensity normalised green value, and I is the intensity. The calculation of these variables is described below. The intensity variable I is only used for reconstruction of the RGB tuple (set of values) and is not used in any yield equation calculations.

#### Calculation of RiGiI from RGB

The calculation of the intensity normalised values requires all red, green, and blue measurements of a RGB tuple. In addition, to ensure full intensity independence, a digitiser offset is preferably subtracted (since the offset associated with a digitiser for digitising measured RGB values in a colour data capture system is obviously not affected by light intensity variation). Through use of an assigned offset value and supply of the RGB values, the intensity normalised values are found as follows:

$$R_i = \frac{(R - k)}{R + G + B - 3k}$$

$$G_i = \frac{(G - k)}{R + G + B - 3k}$$

$$I = \frac{(R + G + B - 3k)}{3}$$

where k is the intensity normalised offset explained above.

#### Yield Equations

In order to test the use of intensity normalised colour values in predicted yield or other grading measures, some test yield equations were developed from data gathered during a



yield trial experiment. During this yield trial experiment, images for many beef carcasses were captured at an operating abattoir and various measures obtained from these data were correlated with the saleable meat yield for each of the respective carcasses. In this way the yield equations relating measured or calculated parameters of the carcasses could be derived by multiple regression analysis (or other statistical analysis techniques) to best fit the data and optimise the fitting or prediction of the actual saleable meat yield.

At a general level of description, the predictive equation takes the form:

$$\text{Property} = x + y.R_i + z.B_i$$

where x, y, and z are constants of positive or negative value derived by the statistical analysis techniques to best fit the data, and  $R_i$  is the intensity normalised red value,  $G_i$  is the intensity normalised green value (or the intensity normalised blue value could be substituted for either the red or green value).

Two particular equations derived for the purpose of comparing the performance of a yield prediction equation using intensity normalised variables with a yield prediction equation using intensity based variables are as follows:

$$\text{Yield 1} = 80.2 - 35.4 \times R_{i1} + 19.8 \times B_{i1} \quad (1)$$

$$\text{Yield 2} = 77.48 - 0.16 \times R_1 + 0.054 \times G_1 + 0.094 \times B_1 \quad (2)$$

where  $R_{i1}$  is the intensity normalised red value of a predetermined "area 1" of the carcass where a good predictive correlation between colour values and yield has been empirically determined,

$B_{i1}$  is the intensity normalised blue value of the same "area 1",

$R_1$  is the intensity based red value for the same "area 1",

$G_1$  is the intensity based green value for the same "area 1", and

$B_1$  is the intensity based blue value for the same "area 1".

These two equations were derived using the same data sets so as to provide equivalent equations for comparing predictive ability using one equation with intensity normalised colour values and the other using intensity based colour values.

To provide more variables and potentially greater predictive value, the predictive equation can take the generalised form:

$$\text{Property} = a + b.D + c.R_i$$

where a, b, and c are constants of positive or negative value derived by the statistical analysis techniques to best fit the data, D is a dimensional parameter relating to the target object, and R<sub>i</sub> is the intensity normalised red or green or blue value, the predictive equation optionally having further terms relating one or more further dimensional parameters relating to the target object and optionally having further intensity normalised red or green or blue value for the same or different sections of the area of the target object.

To test such equations having more variables, after testing and evaluation, a further two yield equations were derived from other data gathered at a different yield trial experiment conducted in an operating abattoir which included objective yield data from tissue sampling and laboratory fat analysis. These further equations are:

$$\begin{aligned} \text{Yield 3} = & 72.31 - 0.0059 \times d_1 - 0.14 \times f_1 + 0.015 \times s_1 + 117.62 \times G_2 \\ & - 23.034 \times R_{13} - 36.385 \times R_{14} \end{aligned} \quad (3)$$

$$\begin{aligned} \text{Yield 4} = & 124.94 + 0.0039 \times d_2 - 0.42 \times f_2 + 0.026 \times s_1 - 0.26 \times R_1 \\ & + 0.13 \times G_1 + 0.077 \times B_3 \end{aligned} \quad (4)$$

where d<sub>1</sub> is the distance from the tail to the hind leg bottom, when projected onto a longitudinal line through the carcass,

d<sub>2</sub> is the distance from the brisket to the tail,

$f_1$  is the ratio  $w/L$ , where  $w$  is the distance from the point where the hook suspending the beef carcass passes through the hind leg to the point at the end of the profile of the butt, when projected onto the longitudinal line, and

$L$  is the length of the carcass,

5  $f_2$  is the ratio  $x/L$ , where  $x$  is the distance from the hook to the point of the armpit, when projected onto the longitudinal line, and  $L$  is the length of the carcass,

$s_1$  is a measure of the degree of "plumpness" of the shape of the butt, e.g. derived by obtaining a measure of the extent of departure of the butt profile from the line from the point of the tail to the bottom of the hind leg,

10  $G_{12}$  is the intensity normalised green value for a predetermined "area 2" of the carcass (different from "area 1") determined to have a predictive correlation to the yield,

$R_{13}$  is the intensity normalised red value for a different "area 3" of the carcass,

$R_{14}$  is the intensity normalised red value for a different "area 4" of the carcass, and

$B_3$  is the intensity based red value for "area 3".

15 Some of these dimensional parameters are indicated on the accompanying drawing showing a beef carcass in side view as presented to the image capture camera.

It is to be appreciated that these yield equations were derived from particular sets of dimensional and colour data captured during particular yield trials conducted at operating abattoirs, including actual saleable meat yield data obtained using conventional grading  
20 techniques for each of the respective carcasses. Hence the equations are illustrative only and different equations would result from the statistical analysis techniques used to derive these equations if applied to other sets of test data from carcasses. For example only, very different equations would result from dimensional and colour data obtained for different species of beef cattle, different sexes of animals, different age groupings of cattle, different pasture or

feeding types and patterns for the cattle (e.g. different types of grasses or pastures, grain fed versus grass fed, different climatic and seasonal conditions, dietary supplements and growth factor or hormone manipulation, etc.), different animal species (cattle, sheep, pigs, goats, etc), and possibly even mechanical processing variables (such as pelt or hide removal techniques 5 which may affect the extent and location of fat left on the surface of the carcase). Hence these equations are illustrative only of the kind of equations that may be used in implementing the method of the present invention to calculate a property of an object utilising the light intensity independent colour measures in a predictive equation.

Also the derived equations will be different depending on the use of selected ones of 10 the numerous variables including dimensional variables, ratios of dimensions, other measures such as the measure of the shape of the butt. The sizes and locations of the predetermined areas of the carcase where colour measurements are taken and used in the predictive equations will very substantially affect the final derived constants in the equations. These particular exemplified two pairs of predictive equations were derived using the same 15 statistical methodology and using the same real data so as to thereby obtain comparative equations for testing the effect of using intensity normalised colour values.

#### Intra-site repeatability

In order to test the stability of the beef carcase system over the duration of a further yield trial in an operating abattoir, a fake carcase having the size and shape of a real beef 20 carcase and having its surfaces carefully coloured so as to closely match the fat and meat tissue colours of a real beef carcase was measured multiple times on a number of days during the period of the yield trials. Over a trial when the fake carcase was presented 37 times over a number of days, yield equations (1) and (3) exhibited only very small changes in the predicted yield - minimum -0.062% and maximum +0.102% deviation from a median

predicted yield. On the other hand, yield equations (2) and (4) displayed a drift of minimum -0.39% and maximum +0.16% from the median.

Likewise the RMS of the changes of the individual yield predictors for the intensity normalised yield equations (1) and (3) had a maximum of 0.048, compared to the RMS of the changes in the individual intensity based predictor of equations (2) and (4) which had a maximum of about 0.3%.

These results show stability and repeatability of the system with the intensity normalised colour values showing substantially better intra-site repeatability.

In fact, during this intra-site test, one of the light bulbs of the carcass illumination system used during image capture failed in one carcass image capture and therefore significantly changed the carcass illumination conditions. The intensity normalised yield equations (1) and (3) showed only very small change in predicted yield and small change in the RMS of the changes for this trial with the failed light bulb, whereas the intensity dependent yield predictive equations (2) and (4) showed very large changes in predicted yield and RMS value for this trial with the failed light bulb. By chance, this demonstrated that the use of intensity normalised equations are robust to such changes in illumination conditions.

#### Inter-site repeatability

To investigate the repeatability of the system between two sites, the fake carcass was presented to the imaging system at multiple times at a different meat processing plant. Using the four yield equations above, the predicted yields for the fake carcass were compared to the results from the other processing plant. These results demonstrated that the intensity normalised colour values showed excellent inter-site repeatability and, in particular, the results were substantially more consistent than with the predictive equations using intensity dependent colour values.

### Lighting sensitivity

To test the sensitivity of the system to lighting positioning during the capture of image data, the arrays of illuminating light sources used to illuminate the carcasses were deliberately moved to different positions and images were captured at each of a number of 5 different lighting positionings. Again the fake carcass was used to enable comparison of the results from the various yield equations. This experiment caused changes in yield predictions of  $\pm 0.2\%$  for yield equations (1) and (3) (the intensity normalised colour values) compared to changes in predicted yield from equations (2) and (4) of  $\pm 1.5\%$ . Thus the use of the intensity normalised colour values shows robustness to lighting misalignment.

### 10 Animal type yield equations

After the completion of numerous yield trials, it was determined that to achieve acceptable levels of yield prediction accuracy, multiple yield equations may need to be developed for different animal types, even when considering beef carcasses alone. Equations based on both statistical methodologies and biological groupings were derived. Six 15 categories were finally selected. These were: Bulls, Cows, Light Grasslike, Heavy Grasslike, Light Grainlike, and Heavy Grainlike. "Light" and "Heavy" refer to carcass weight, and "Grasslike" and "Grainlike" refer to tissue colour. The six equations were derived using statistical methodologies as outlined earlier. The equations have a generally similar appearance to the yield equations given earlier but have different variables (depending on 20 which dimensional data, colour patch values, etc. show the best correlations and predictive ability for yield for each of the six carcass categories) and also different co-efficients.

However, all six equations used intensity normalised colour values and showed good yield predictive ability and inter-site and intra-site repeatability and illumination insensitivity. In use, each carcase was categorised into one of the six predetermined categories and the data captured was then used for the input to the respective equation for the relevant category to provide the yield prediction.

### Yield Equation Labels

As mentioned, the BCS yield prediction accuracy relies upon application of the appropriate yield equation from one of the six categories mentioned above. The values for the Wy and CompWy for a particular beef carcass side will therefore have been derived from the yield equations applicable to its category.

Wy = Predicted wholesale saleable meat yield

CompWy = Component predicted wholesale saleable meat yield for the BCS

### Combined Equation Weightings

The BCS produces not only its prediction of saleable meat yield, but also a yield that forms part of a combinatorial equation. This component yield (CompWy) was added to a weighted CAS predicted yield representing the currently selected carcass type. "CAS" refers to a "Chiller Assessment System" (available from Viascan Quality Assessment, of Beenleigh, Queensland, Australia) which provides measures relating to meat yield after further analyses later in the processing operation in a chiller. This weighted addition must be applied off-line at the end of the processing operations in the abattoir. The formula that is implemented was as follows:

$$\text{Combined Wy} = \text{BCS\_CompWy} + k' \times \text{CAS\_Wy}$$

where  $k'$  is defined according to which carcass type has been selected. The appropriate values are shown below in the table. Note that the CAS yield equations exist for only three carcass categories. These are: bull, cow, and table beef (where the "table beef" category includes all beef from the four subcategories of the BCS).



BCS Yield Category	k'	CAS Yield Category
Bull	0.4627	Bull
Cow	0.8095	Cow
Light grain	0.6057	Table beef
Heavy grass	0.8136	Table beef
Light grass	0.7751	Table beef
Heavy grain	1	Table beef

Table: CAS yield weightings by category

### Conclusions

The use of colour normalised colour values in yield equations has been found to provide more accurate and therefore more reliable yield predictions of beef carcasses than measured colour values which are influenced by light intensity at the time and place of the image capture even if considerable measures have been taken to calibrate the equipment to remove equipment, site and time induced variables and even if considerable measures have been taken to provide controlled lighting conditions at the image capture station.

The invention has been mostly described herein and illustrated in connection with predicting yield of a meat carcase, i.e. the amount of saleable meat, particularly a beef carcase. "Yield" is the primary measure used for carcase grading in Australia where the invention has been developed. However, in other countries or regions, there can be different parameters used to grade meat such as meat carcasses.

For example, in Europe there is a scoring or grading system known as "EUROP" which involves determining one grading measure for the shape or "conformation" of a carcase (which categorises the degree of fatness or fullness of the carcase) and a "fat score" (which provides a score or grading for the overall fat coverage of the carcase). The present invention is equally applicable to the process of calculating the conformation and fat scores in

the EUROP system for a meat portion or carcase using light intensity independent colour measures in appropriate predictive equations. It will be appreciated that the capture of colour data for a carcase (together with other data such as dimensional data), can be used in an analogous manner to that described above for developing a yield predictive equation to  
5 develop equations to provide EUROP conformation and fat score measures. The use of light intensity independent measures of colour values in such conformation and fat score predictive equations will improve the intra-site and inter-site repeatability of the system and light orientation insensitivity as established for the yield predictive equations.

In the United States, there is a further meat grading system developed by the USDA.  
10 This USDA grading system is based on analysis of the rib eye muscle colour and size and on the fat weight. The system involves the allocation of two grading measures known as the "yield grade" and the "quality grade". As with the EUROP grading system, the present invention using light intensity independent measures of colour values can be used in predictive equations for the "yield grade" and "quality grade" under the USDA grading  
15 system by developing such equations using multiple regression analysis techniques or other statistical methodologies. The use of light intensity independent colour values in such equations for the USDA grading system will have the same advantages as described above for the Australian yield equations.

## CLAIMS

1. A method of analysing colour image data relating to a target object to derive or predict a property of the object of which colour is an indicator, the method including the step of processing the colour data to derive light intensity independent measures of colour values,  
 5 followed by the step of calculating the property of the object utilising the light intensity independent colour measures in a predictive equation in which the light intensity independent colour measures are variables and the property of the object is calculated from solving the predictive equation.

2 A method of analysing colour image data relating to a target object as claimed in  
 10 claim wherein the colour image data comprising RGB colour values are obtained by digitising measured RGB values from a colour data capture system using a digitiser, the digitiser having a predetermined intensity normalised offset "k", and wherein the light intensity independent measures of colour values are determined from the equations:

$$R_i = \frac{(R - k)}{R + G + B - 3k}$$

$$G_i = \frac{(G - k)}{R + G + B - 3k}$$

15 
$$I = \frac{(R + G + B - 3k)}{3}$$

where  $R_i$  is the intensity normalised red value,  $G_i$  is the intensity normalised green value, and  $I$  is the intensity, the intensity variable  $I$  being only used for reconstruction of the RGB colour values.

3. A method of analysing colour image data as claimed in claim 1 or 2 wherein the predictive equation is developed from data gathered during a data gathering experiment using images captured for real target objects, the method comprising correlating the light intensity independent colour measures obtained from these data with the actual measured property of each of the real target objects to derive the predictive equation by statistical analysis techniques to best fit the data and optimise the prediction of the actual measured property from the light intensity independent colour measures.

4. A method of analysing colour image data as claimed in claim 3 wherein the predictive equation takes the form:

$$\text{Property} = x + y.R_i + z.B_i$$

where  $x$ ,  $y$ , and  $z$  are constants of positive or negative value derived by the statistical analysis techniques to best fit the data, and  $R_i$  is the intensity normalised red or blue value.  $G_i$  is the intensity normalised green or blue value.

5. A method of analysing colour image data as claimed in claim 3 wherein the predictive equation takes the form:

$$\text{Property} = a + b.D + c.R_i$$

where  $a$ ,  $b$ , and  $c$  are constants of positive or negative value derived by the statistical analysis techniques to best fit the data,  $D$  is a dimensional parameter relating to the target object, and  $R_i$  is the intensity normalised red or green or blue value, the predictive equation optionally having further terms relating one or more further dimensional parameters relating to the target

object and further intensity normalised red or green or blue value for the same or different sections of the area of the target object.

6. A method of analysing colour image data as claimed in any one of the preceding claims wherein the object is a meat object, the property of the meat object being a quantative  
5 meat or carcass quality measure, the method including the steps of capturing and processing colour data for the meat object to derive light intensity independent measures of colour values, followed by the step of calculating the quantative meat or carcass quality measure for the meat object utilising the light intensity independent colour measures in a predictive equation in which the light intensity independent colour measures are variables and the  
10 quantative meat or carcass quality measure of the meat object is calculated from solving the predictive equation.

7. A method of analysing colour image data as claimed in claim 6 wherein the quantative meat or carcass quality measure is a measure selected from the set consisting of:  
the "yield" of a carcass in a standard carcass grading system,  
15 the "conformation" of a carcass in a standard carcass grading system,  
the "fat score" of a carcass in a standard carcass grading system,  
the "yield grade" of meat from a carcass in a standard meat grading system, and  
the "quality grade" of meat from a carcass in a standard meat grading system.

8. A method of analysing colour image data as claimed in claim 7 wherein the  
20 quantative meat or carcass quality measure comprises the "yield" of a carcass as defined in the standard Australian carcass grading system.

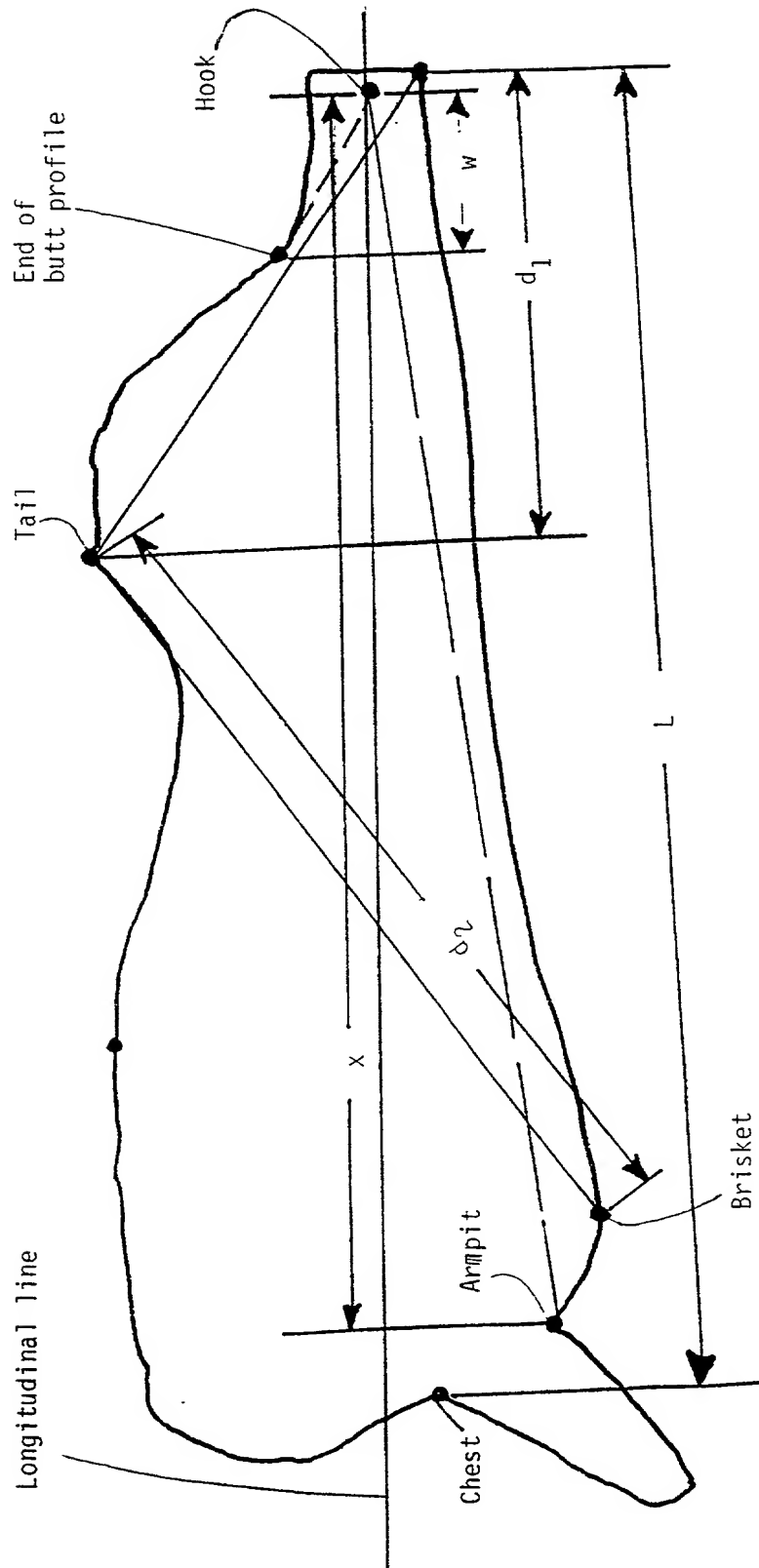
9. A method of analysing colour image data as claimed in claim 7 wherein the quantative meat or carcass quality measure comprises the "conformation" of a carcass in the EUROP standard carcass grading system.

10. A method of analysing colour image data as claimed in claim 7 wherein the quantative meat or carcase quality measure comprises the "fat score" of a carcase in the EUROP standard carcase grading system.

11. A method of analysing colour image data as claimed in claim 7 wherein the  
5 quantative meat or carcase quality measure comprises the "yield grade" of a meat object in the USDA standard meat grading system.

12. A method of analysing colour image data as claimed in claim 7 wherein the quantative meat or carcase quality measure comprises the "quality grade" of a meat object in the USDA standard meat grading system.

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<b>DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION</b> <b>(37 CFR 1.63)</b>  <input checked="" type="checkbox"/> Declaration Submitted with Initial Filing      OR <input type="checkbox"/> Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)	Attorney Docket Number	743-P-2-USA
	First Named Inventor	KURT MALMSTROM
	COMPLETE IF KNOWN	
	Application Number	/
	Filing Date	
	Art Unit	
	Examiner Name	

As the below named inventor, I hereby declare that:

My residence, mailing address, and citizenship are as stated below next to my name.

I believe I am the original and first inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled:

IMAGE DATA ANALYSIS OF OBJECTS

(Title of the Invention)

the specification of which

☐ is attached hereto

OR

☒ was filed on (MM/DD/YYYY)

07/10/2000

as United States Application Number or PCT International

Application Number PCT/AU00/00830 and was amended on (MM/DD/YYYY) (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, inventor's or plant breeder's rights certificate(s), or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached?	
PQ 1544 /	AUSTRALIA ✓	07/09/1999 ✓	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
PQ 2828 /	AUSTRALIA ✓	09/14/1999 ✓	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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☐ Additional inventors are being named on the \_\_\_\_\_ supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto.